

## **Flat ridge fiber for fundamental Model Power Scaling from Single Aperture**

Award no: FA8655-07-1-3006

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Content

<b>FLAT RIDGE FIBER FOR FUNDAMENTAL MODEL POWER SCALING FROM SINGLE APERTURE .....</b>	<b>1</b>
<b>1 INTRODUCTION .....</b>	<b>1</b>
<b>2 MANUFACTURING .....</b>	<b>1</b>
2.1 TARGET .....	1
2.2 FIBRE SPECIFICATIONS .....	1
2.3 DRAWN FIBRE GEOMETRY .....	2
2.4 FIBRE ABSORPTION .....	3
2.5 MODE FIELD DISTRIBUTION .....	4
<b>3 CONCLUSIONS .....</b>	<b>5</b>
<b>4 NEXT STEPS .....</b>	<b>5</b>

### **1 Introduction**

This report continues the interim report delivered on September 2007. It covers the experimental results on a fiber made to test the manufacturing technique.

As the test results are encouraging, the project will continue by manufacturing two more fibers on the specs presented on previous report.

### **2 Manufacturing**

#### **2.1 Target**

The main target of the trial was to prove the concept for the manufacturing technique. As the design and assembly of various parts involved several new processes, we aimed to demonstrate:

- subcontractor's capability to perform the glass grinding according to the specs
- internal glasswork capability to assembly the parts
- fiber drawing effects on fiber shape: ridge, slab and outer cladding.

Finally, since the manufacturing process proved to be successful we performed several tests on the fiber to evaluate its performance.

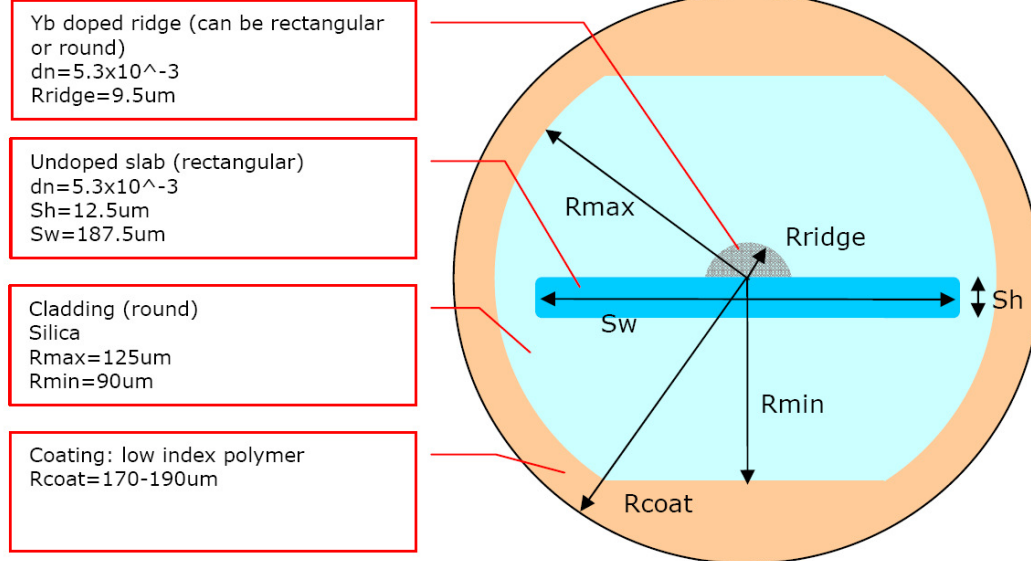
#### **2.2 Fibre specifications**

The fibre specifications were taken from the previous report:

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13. SUPPLEMENTARY NOTES					
14. ABSTRACT This report results from a contract tasking Liekki Oy as follows: (i). Design, Growth and Fabrication of Preforms. At least 3-4 preforms with 2 or more different core dimensions and refractive indices will be produced during this project. Early design and simulation work will be carried out at VTT to provide several iterations of target cross sections for the composite ridge fiber. Preliminary evaluations indicated that the area of the Yb doped core can be > 2-4 times greater in a rib waveguide than in a standard step index fiber while still delivering single mode. The planar glass structure also provides a great deal of flexibility in selecting the relative dimensions of the active core, the undoped slab and the surrounding cladding. Several simulations will therefore be conducted to identify two or three of the most promising target cross sections. In addition to preform growth, the applicability of existing bonding and grinding technologies to flat ridge structures will be evaluated. . Bonding techniques for different glass structures utilized to attach the different parts of the flat ridge fiber perform are especially challenging because of the potential impact of the interface quality on the final mode shape. Similarly, grinding tolerances may be more stringent than for standard fibers and these will have to be carefully evaluated. Ridge Fiber Drawing: Whereas the technology elements for drawing rectangular fibers were successfully developed and commercialized at Liekki in the past year, this was implemented in practice only for clad passive .ibers used to deliver diode radiation. The application of the drawing technologies to the case of active ridge fibers is especially challenging because the fibers cannot spin during the process. On this objective we will address key fiber drawing challenges sleeving and drawing speed Preliminary lasing experiments of selected prototype flat ridge fiber. These will be constructed as feasibility demonstrations designed to provide proof-of-concept validations of the basic ridge fiber approach. The experiments will be conducted at Liekki, using in-house diodes, splicing equipment, optics and test equipment.					
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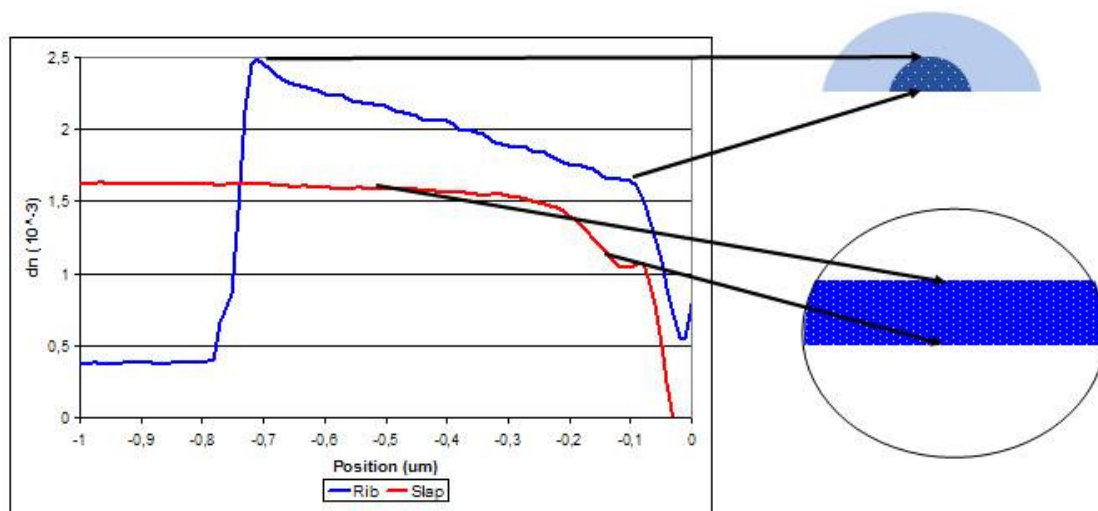


Fiber specs A: 250um cladding



**Figure 1: Fiber design specifications**

Because this was a trial for testing the manufacturability we used materials we already had in house even though they were not fully in specs. Figure 2 shows the actual refractive index profile taken from the doped preform and passive rod.

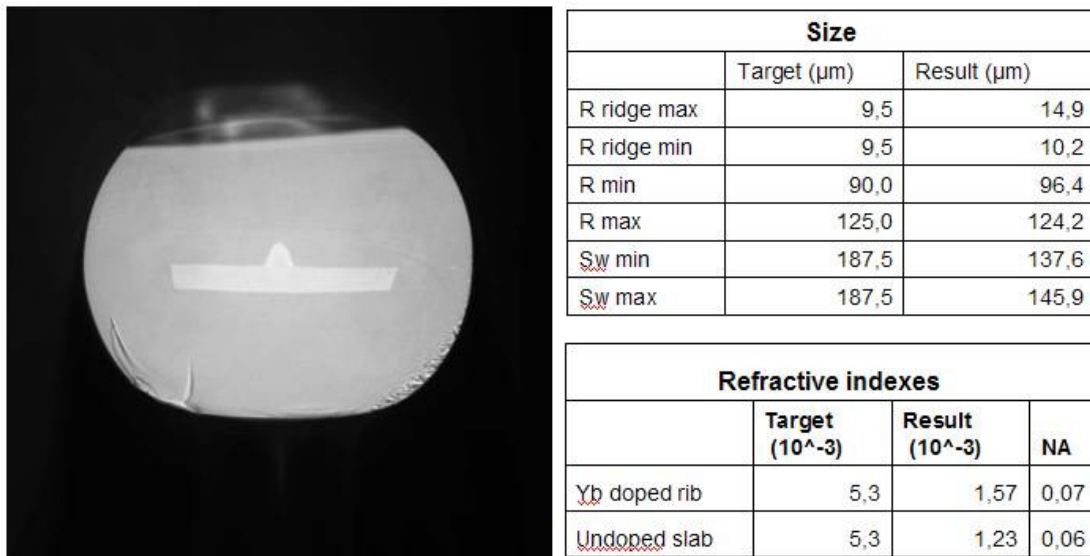


**Figure 2: Refractive index difference for doped ridge and passive slab**

The main deviation from the specs is the relative index difference between ridge and slab ( $dn_{ridge} - dn_{slab}$  should have been lower than  $1 \times 10^{-4}$ ). The absolute value of the index difference is not relevant for the fiber.

### 2.3 Drawn fibre geometry

The geometry of the drawn fiber is presented below:



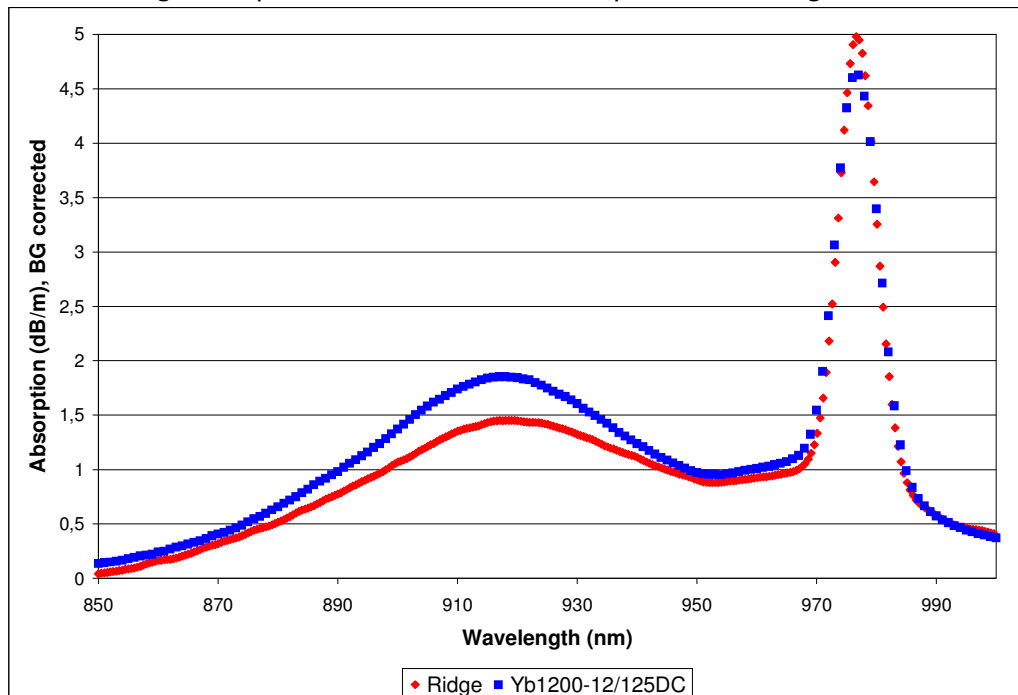
**Figure 3: Drawn fiber geometry**

The main achievement we demonstrated is that we managed to manufacture the fiber that preserves the ridge and slab geometry. Also the structure has good mechanical strength and has no bubbles.

The dimensional and index difference differences are due to the materials available and will affect the performance of the fiber, as shown below.

## 2.4 Fibre absorption

The cladding absorption of the drawn fiber is presented in figure 4:

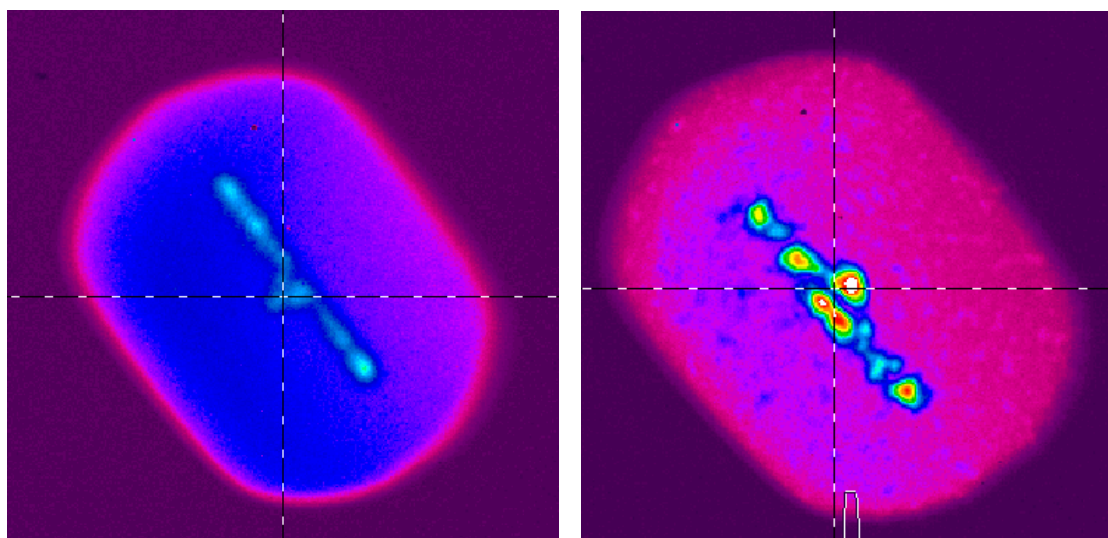


**Figure 4: Drawn fiber absorption spectrum**

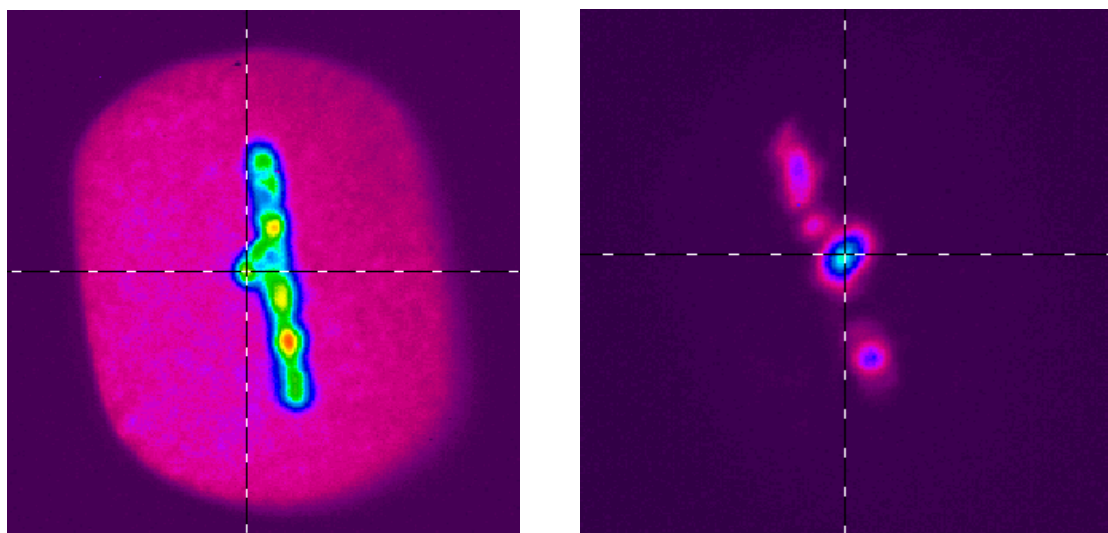
The absorption spectrum is as expected. The Yb1200-12/125DC fiber was taken as reference since according to the calculations it should have an absorption spectrum close to the ridge fiber.

## 2.5 Mode field distribution

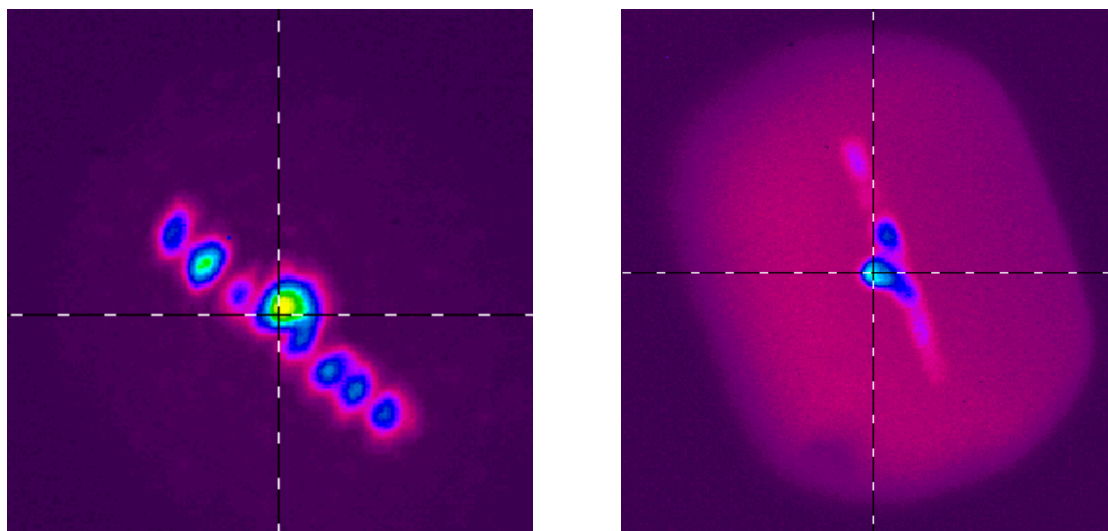
We analyzed the mode field distribution for various coiling and fiber.



The fiber does not lase if the slab is on the outer side of the coil (left side image). The fiber lases when the ridge is on the outer side of the coil (right side image). The fiber was coiled at 15cm diameter and the waveguide is strongly multimode.



The coiling diameter plays an important role in modal composition: 13.5cm coiling diameter (left): highly multimode, 16cm coiling diameter (right): closer to singlemode operation.



The modal composition can be adjusted by fiber length: left side image: 18m, right side image: 8m.

This behavior is in line with the simulation predictions. Because the index difference between ridge and slab is higher than specified and also the slab width is lower than specified, the fiber has a tendency to be multimode and is very sensitive to coiling diameter.

### 3 Conclusions

We demonstrated that we can manufacture the doped ridge fiber strong and without bubbles.

Some fiber parameters were out of specs because this was a trial for the manufacturing process.

As predicted by the simulation, the fiber with too narrow slab has the tendency to become multimode but this can be compensated by proper coiling and adjusting the fiber length.

### 4 Next steps

We already started the manufacturing of two new fibers with proper materials. These fibers will be made according to the design specs. The target is to demonstrate the stable single-mode operation.